U. S. ARMY ELECTRONICS MATERIEL AGENCY.

PRODUCTION ENGINEERING MEASURE

DA - 36 - 039 - SC - 86727

SILICON PLANAR EPITAXIAL TRANSISTOR

TYPE 2N2193

SILICON GROWN DIFFUSED TRANSISTOR

TYPE 2N336

SECOND QUARTERLY REPORT

31 JULY 1962
31 OCTOBER 1962

GENERAL ELECTRIC

U. S. ARMY ELECTRONICS MATERIEL AGENCY.

PRODUCTION ENGINEERING MEASURE

DA - 36 - 039 - SC - 86727

SILICON PLANAR EPITAXIAL TRANSISTOR

TYPE 2N2193

SECOND QUARTERLY REPORT

31 JULY, 1962
31 OCTOBER, 1962

(S. G. Johnson)
PROJECT MANAGER

TABLE OF CONTENTS

I. AREA OF WORK - IMPROVED KPR RESOLUTION (C. LOGAN).

1 A. Work Item - Improved light collimation during KPR exposure.

B. Abstract - The investigation involving the evaluation of commercially available KPR-exposure-alignment gear along with departmental designs for attaining optimized light collimation has resulted in the abandonment of outside source considerations in favor of modification of our present gear with a highly collimated light source of our own design.

C. Purpose - The significance of a collimated light source during KPR exposure is to minimize light scattering, refraction and wafer-mask contact effects during the exposure of the KPR oxide masking pattern, thus minimizing pattern resolution degradation.

D. Narrative and Data - Commercially available light sources having the collimation characteristics desired, could not be readily adapted to our present equipment designs which have desirable features above and beyond those incorporated into the commercially available equipment. Flexibility relative to additional improved optics, light pattern dimension control, and exposure accessories and adaptors is limited with the commercial equipment, while provisions have been made for a wide range of flexibility with the departmental design.

E. Conclusions - A highly collimated Mercury Arc, light source satisfactorily meets all requirements of high resolution exposure for KPR masking of window etching processes.

F. Program for next Quarter - Light source will be built and made an integral part of our present KPR-alignment-exposure gear in readiness for debugging and evaluation.

---

2 A. Work Item - Mask-Wafer "Contact" Exposure Effects.

B. Abstract - The modified gimbal ball joint table has been made an integral part of the exposure-alignment fixture design.

C. Purpose - The present design of the gimbal table as used with the vacuum hold down allows for possible restriction in obtaining good intimate contact between mask-wafer prior to exposure, whereas a ball joint design provides for a more "free" movement, thus ensuring a more controllable and reproducible exposure.

D. Narrative and Data - The KPR exposure-alignment gear has been modified to replace the double gimbal "seat" by the ball joint "seat" design. Present processing is realizing the benefits of this modification.

This Work Item is completed.

---

3 A. Work Item - High Resolution Masks

B. Conclusions

Pattern resolution for the KPR glass masks, which we are currently purchasing from mask vendors, has been advanced to the point where the transition from opaque to clear areas is less than one micron. This is better than the inherent resolution of the KPR process. As a result, the present optimized mask resolution is adequate and these masks are presently being used in production.

This work item is therefore regarded as complete.

II. AREA OF WORK - CONTACT EVAPORATION AND ALLOYING (C. LOGAN)

1 A. Work Item - Improved Substrate Heater Design.

B. Abstract - Total emphasis is being placed upon the infra-red lamp, substrate heater design. Heaters have been fabricated and evaluation efforts are under way.

C. Purpose - Consistent and uniform aluminum contact surfaces and alloying necessitates controlled deposition and alloy temperature cycles as exhibited by the substrate heater. The particular heater designs mentioned should minimize gradient effects characteristic of large area heaters.

D. Narrative and Data - The heater design consists of six lamps contained and positioned under a quartz plate, with the bottom side sand blasted and silver coated. Temperature control is attained through the use of a thermocouple which is located directly beneath the plate (above the lamps). The thermocouple is exposed to the lamps and responds to I.R. radiation and not conducted heat. This minimizes problems associated with attaining and maintaining of intimate contact between the thermocouple and a surface during heat cycling, thus insuring reproducibility from run to run. Temperature profiles have been made of the quartz substrate plate and a usable area (4" x 6") mapped out at the desired temperature ($\pm$ 5°C)

E. Conclusions - The infra-red heater design will meet the requirements as fixed by the contact process. Proper control has been attained and a much simpler design relative to previous conduction type, resistance heaters.

F. Program for next Quarter - The I.R. heater will be installed on a vacuum system, debugged and proven as a reliable substrate heater for contact evaporation and alloying.

---

2 A. Work Item - Temperature Control Improvements

B. Abstract - Proportional current limiting control units have been installed on all vacuum systems.

C. Purpose - "On-Off" temperature control is characterized by a temperature range control rather than point temperature control, along with initial overshoot while current limiting control provides only enough current to maintain the control temperature and ensure more reproducible deposition-alloy cycles.

D. Narrative and Data — The controller units used during contact evaporation and alloying for indicating and maintaining constant temperature control have been modified and adaptor units installed to provide current limiting control. Problems such as temperature overshoot and controller "runaway" have been minimized.

E. Conclusions — The proportional current limiting control units are functioning according to specifications relative to required temperature control. This work item is considered complete.

---

3 A. Work Item - Regulated Leak Consideration

B. Conclusions — This work has been pre-empted by the vacuum deposition process. (See 4A.)

---

4 A. Work Item - Vacuum Deposition Process

B. Abstract - The major process variable relative to bondability, and electrical parameter effects as associated with good consistant alloying proved to be the deposition temperature. Elevated deposition temperature and low pressure result in improved reproducibility and reliability of the contact process and improved aluminum-silicon alloy and T.C.B.

C. Purpose - To develop a constant process which would minimize the critical nature of TCB, Thermo Compression Bonding and promote reproducibility of alloy regions having negligible effect on the electrical parameters.

D. Narrative and Data — Consistent alloying is dependent upon wettability or the ease with which the aluminum wets the silicon surface to promote an alloy. Depositions carried out at elevated temperatures establish a much more adherent or more intimate contact condition between the aluminum layer and the silicon surface. If in fact, the deposition is conducted above the aluminum silicon eutectic temperature wetting and alloying occur simultaneously.

The effect of substrate temperature upon thermo-compression bondability arises from deposited aluminum film density or particulate build up of the film during deposition. Ease of bonding is dependent upon "softness" of aluminum contact surface which is in turn dependent upon film density and the alloy. Hot substrate vs. cold substrate depositions result in completely different aluminum contact bondability characteristics.

E.	Conclusions	Elevated substrate deposition temperatures result in improved and more consistent alloyed aluminum contacts, and a more reproducible and reliable process.
F.	Program for next Quarter	Incorporate the elevated substrate temperature deposition as part of the existing contact formation processes.

III. AREA OF WORK - COLLECTOR ETCHING (C. LOGAN)

1 A. Work Item - Surface Masking.

B. Conclusions

As stated in the last quarterly report in the conclusion section of this work item, this improved technique has virtually eliminated mask failures during collector etch and proved to be a much more reliable process. It has been adopted and is part of the standard collector etch process.

IV. AREA OF WORK - BORON DIFFUSION (A. R. DI PIETRO)

1 A. **Work Item** - Replace present B_2O_3 solid source process by a BCl_3 gaseous source process.

B. **Abstract** - The diffusion furnace and gas train have been assembled and put into operation. A series of runs has been initiated to assess the adaptability of this process to manufacturing.

C. **Purpose** - The goal of the work during this quarter was to acquire and manufacture parts and equipment for the gas train and furnace and to assemble them into a diffusion apparatus. In addition, a series of runs was to be started for the purpose of determining the ease of control, reproducibility and uniformity of the BCl_3 diffusion process.

D. **Narrative and Data** - Prior to the installation of the completed furnace assembly according to the design discussed in the last quarterly report, it was discovered that the flat zone heater had opened. A new heater element was purchased and installed and the furnace now maintains a diffusion flat zone nearly twice as long as before the breakdown. Except for minor alterations necessitated by results obtained in optimizing the diffusion process, the furnace design and assembly is considered as completed.

In the earlier developmental work on the BCl_3 diffusion process, prior to the period of this contract, certain features of the process were established. These features are:

1. Exceptional uniformity in properties resulting from boron diffusion.

2. Some evidence that the BCl_3 process does not introduce crystal damage during diffusion.

3. Simpler furnace requirement, i.e. one flat zone instead of two.

4. Impurity source concentration can be varied over a large range and can be held constant within a close tolerance. This gives versatility to the BCl_3 process which is not available in B_2O_3 diffusion.

However, in introducing a process into a manufacturing cycle, two very important criteria which must be met are:

1. Reproducibility. The process performance under this criterion must be such that the material output from this process has a certain probability of falling within a target area. This target area must be consistent with the overall manufacturing cycle.

that is, the extremes in results which can be tolerated from a given process are determined by the degree of change necessary in subsequent processes to bring the ultimate product within specifications.

2. Ease of control - The process must be such that manufacturing non-technical personnel, operating from written instructions, can obtain satisfactory results on a daily basis. In addition, the process must have sufficient stability that in the event of a shut down or other interruption in the daily routine a process engineer can restore the system to satisfactory operation within a short time.

We have initiated a series of runs to assess the degree to which the BCl_3 process meets these two criteria. Our approach is to systematically determine that set of process control parameters which will optimize both the stability and reproducibility of the process. One of the controlling parameters in this process is the thickness of the oxide barrier which is grown over the diffused areas prior to diffusion. The process depends on the controlled failure of this oxide analogous to the standard gallium diffusion process. Initial results indicate that one of the causes for unsatisfactory reproducibility will be changes in this oxide thickness during the course of a run.

E. Conclusions

It appears that the present equipment design will be satisfactory. However, initial results indicate that the main process problem will involve the change in oxide thickness during a diffusion run. Unless significant improvement in results on lot to lot reproducibility is obtained in the first part of the next quarter, it appears that our present BCl_3 process is not capable of giving the daily reproducibility which we can obtain with B_2O_3.

F. Program for next Quarter

Progress on this work item in the next quarter will consist of optimizing and finalizing operating procedures for BCl_3 diffusion in order to attain a satisfactory degree of lot to lot reproducibility.

V. AREA OF WORK - PHOSPHORUS DIFFUSION (J. F. WHOLEY)

1 A. **Work Item** - Improved Source Heater for Phosphorus Diffusion

B. **Abstract** - Temperature control attained with the new improved heaters on the initial series of debugging runs appears very promising.

C. **Purpose** - The objectives of this work item were:

a. To decrease the time interval between the loading of the P_2O_5 and the attainment of a stable temperature at the desired operating point.

b. Automatic control of temperature at the operating point, with a maximum fluctuation of about $\pm 1^{\circ}C$.

D. **Narrative and Data** Construction and installation of an infra-red heated source zone tube furnace are complete. Debugging runs are under way with promising initial results in terms of temperature control. The control circuit which powers the infra-red heater gives a swing of $\pm \frac{1}{2}^{\circ}C$. for the heater zone by itself.

E. **Conclusions** Redesign or alternation of the infra-red heater will not be necessary.

F. **Program for next Quarter** Determine the degree of control attainable using the infra-red system. Control criteria will be

a. The reproducibility of heat-up time from the instant the P_2O_5 is loaded until the desired temperature level is reached, and

b. The range of temperature fluctuation from this point until the end of the run.

---

2 A. **Work Item** - Improved Technique of Loading Phosphorus Source Boats

B. **Abstract** - Construction of a dry box to house the loading operation has been delayed pending negotiations with a vendor to supply quantities of dry phosphorous pentoxide in sealed containers. Samples of these containers are scheduled for delivery by November 15.

C. **Purpose** - Improvement in the technique of loading the phosphorus source boats to minimize exposure to room air humidity and to achieve uniform effective P_2O_5 source surface area will improve the uniformity of phosphorus concentration and junction depth.

D. Narrative and Data	Work on this item has not progressed according to plan because of the decision to emphasize a preweighed, sealed quantity of phosphorus pentoxide as the principal element in the attempt to improve control of the loading process. The present loading technique, while extremely rapid, is volumetric and therefore subject to variations in the bulk density of the phosphorus pentoxide both in the bottle and as packed into the loading tool.
E. Conclusions	Individual operator discretion in the preparation of the right quantity of source material for use in phosphorus diffusion can be removed by the use of commercial, anhydrous, pre-weighed and sealed containers.
F. Program for next Quarter	Evaluate the use of pre-weighed phosphorus pentoxide ampoules in terms of ease and speed of loading as well as the subsequent reproducibility of sheet resistivity and phosphorus glass thickness on wafers. It is anticipated that this evaluation will necessitate the construction of a simple dry box for ambient protection during the period when the ampoule is opened and the source is loaded.

VI. AREA OF WORK - COLLECTOR CONTACT TO THE HEADER (R. H. LANZL, J. L. DURSO, J. RICHARDSON)

1 A. Work Item - Reduction in Size of Preform.

Increased capacity of preform and pellet mount equipment. Alternative pellet mounting process. Feasibility of elimination of preform.

B. Abstract - Progress in each of the three work areas was as follows:

1. Preforms were mounted automatically on revised preform mount equipment. It was determined, however, that additional, more reliable revisions were necessary.
2. Pellets were mounted without preforms on existing headers (100 millionths gold plate) using resistance heat (through application of electrodes in the immediate vicinity of the pellet). Mechanical results at this time appear to be extremely good.
3. As mentioned above, a different approach to mounting was attempted. A commercially available pellet mount machine which incorporates the resistance heating technique was evaluated.

C. Purpose - The goal during this report period on work with collector contacts has been directed.

1. Toward completion of effort in automatic mounting of preforms at increased rates, on existing equipment.
2. In exploring and evaluating the possibility of eliminating the necessity of preforms--particularly through the use of improved pellet mount equipment. Success in this area should further improve existing output capabilities and result in easier, more consistent pellet mounting.

D. Narrative and Data - Work details are as follows:

1. A quantity of 2N2193 headers had preforms mounted on existing equipment after minor modifications had been made. Results were somewhat erratic and set up times excessive. To assure reliable results, a complete redesign of header holding and positioning was completed and is now under construction. Incorporated in these revisions are plans to increase by 50% the present speed of the preform mount machine using a preform thickness between 0.0005 and 0.001 inch.

2. A quantity of 2N193 headers had pellets mounted without preforms. The machine used, of the resistance heating type mentioned, was adjusted to provide a uniform fillet of gold-silicon eutectic around the pellet. Devices with pellets so mounted were subjected to flexing in such a manner that the "bond" could be visually examined. Additional devices will be subjected to the standard electrical tests to establish satisfactory electrical performance.

3. The resistance pellet mount machine available commercially was evaluated for a short period of time with respect to rate, quality of bond and general operating characteristics. Generally, improvements over existing type equipment in each of these areas were noted. This machine gave good mechanical pellet mounting results, especially without preforms and appears to lend itself extremely well to better and faster pellet mount equipment.

E. Conclusions

1. Preforms can readily be mounted on automatic equipment with satisfactory results--provided proper tooling is available.
2. One hundred millionths gold, which is the thickness of existing header plating, is of sufficient quantity to produce a good mechanical pellet bond without a preform. It thus appears that elimination of the preform may be feasible.
3. Resistance type pellet mounting deserves further investigation both in conjunction with the program to eliminate preforms and in its ability to provide a better, faster technique of mounting.

F. Program for next Quarter

Work during the next report period should:

1. Result in 2N2193 preforms being placed automatically in production.
2. Point out the feasibility of:
   a. Eliminating preforms through the use of properly plated headers to provide comparable quality, or better devices.
   b. Using resistance heating pellet mount techniques in mounting without preforms. Further, a better evaluation of this process for possible use in more automatic equipment will be studied.

2 A. Work Item - Reduction of the Corroding Species by Improving Cleaning and Tighter Inspection of Purchased Material (F. K. GLASBRENNER, R. KOBLER).

B. Abstract - During this period an intense investigation of "As Received" material conditions together with processing parts through cleaning phases of fabrication was initiated.

C. Purpose - To determine degree of control of incoming material and effectiveness of cleaning procedures presently employed on production line. Experiments will be conducted to determine effect of cleaning parts upon device performance and reduction of the corroding species.

D. Narrative and Data - Following outline as presented in first quarterly report the results of our investigation, thus far, is as follows:

a. Cap

1. Identification of material and its condition.

a. Base material by spectrographic analysis.

Chemical Composition: % By Weight

	Spec.	Actual Analysis*
Nickel & Cobalt, Min	99.0	99.471
Magnesium	0.01-0.08	0.078
Titanium	0.01-0.05	0.010
Manganese, Max	0.35	0.180
Iron, Max	0.20	0.041
Copper, Max	0.15	0.014
Carbon, Max	0.15	0.115
Silicon, Max	0.15	0.085
Sulfur, Max	0.008	0.006

* Analysis run by Material & Processes Laboratory who estimate accuracy of impurity measurements to be within 5%. Thus material is well within drawing specifications.

b. Base Material's Fabricated Cleanliness by Metallographic Section Examination.

Photographs were taken of surface conditions but did not indicate any significant visual contamination. However, cross sections are being made to study grain structure and observe any irregularities of surface interface.

c. Surface Contamination by infra-red spectrophoto metric analysis of "As Received" material: data obtained by M&P Laboratory.

Fifty caps were washed and their surface contaminants were extracted. Organic material was found to be present, in Order of Magnitude of 25 ppm. Positive identification of type of organics was not pursued due to small quantity found. However, it was possible to conclude that sulfonated and metallic soap base compounds were not present on parts which would be hard to remove by trichloroethylene degreasing.

2. Cap cleaning and line processing

a. Effectiveness of line processing by metallographic examination:

Photos were taken of the surface after cleaning but no significant difference was visually discernable. Cross sections are being obtained to study effect upon grain size for comparison to "As Received" material.

b. Effectiveness of line processing by infrared spectrophotometric analysis:

The effectiveness of our cleaning processes is dramatically illustrated by this technique where the organic contaminations have been reduced from 25 ppm. to less than 2.3 ppm.

3. Alteration of part or process drawings to improve quality.

At this time it is evident that the material specifications and effectiveness of cleaning are being complied with and are very effective regarding preparation of part prior to use. Therefore, no change in drawing or process will be initiated at this time.

b. <u>Preform</u>

1. Identification of material and its condition.

a. Base material by spectrographic analysis:

Chemical Composition: % By Weight

	Spec.	Actual Analysis*
Sb	0.60 (Nom)	0.610
Ca., Max	0.0003	$<$ 0.0001
Cu., Max	0.002	0.0025
Fe., Max	0.002	0.0001
Pb., Max	0.0001	-
Mg., Max	0.002	$<$ 0.0001
Si., Max	0.0001	0.0001
Ag., Max	0.002	0.003
Total Impurities, Max	0.010	0.0059

* Analysis run by M&P Laboratory, who would not certify degree of accuracy on individual impurities, but estimate total impurity figure to be within 5% which is criteria whereby this material is felt to comply with the specifications.

b. Base material's fabrication cleanliness by metallographic examination.

Visual examination indicated trace of foreign material may be present on surface in as received condition direct from vendor.

c. Surface contamination analysis of material as received by infra-red techniques. Data obtained by M&P Laboratory

Ten feet of gold-antimony ribbon was extracted and organic material was found to be present, in Order of Magnitude of 20 ppm. Again, positive identification of type of organics was not pursued due to small quantity found. A reasonable guess is that some lint from the paper used to cover layers of ribbon, in spool form, is present which shows up as organic material.

d. Dimensional check for compliance to drawing specifications:

	Spec.	Measured Dim.
Width	.040 $\pm$.002	.045
Thickness	.0005 $\pm$.0002	.001

Deviation from drawing specifications was permitted to exhaust stock supply prior to compliance by vendor to new thinner preform dimension. All new material will be ordered to new specifications.

2. Preform Cleaning

   a. Effectiveness of cleaning by infra-red analysis.

      This work is in process and will be reported in the next report.

C. <u>Header</u>

1. Identification of base material and its condition.

   Visual examination of surface conditions indicated no obvious contamination, but observations at higher magnification (400x) indicates differences in grain size between vendors.

   First attempt to analyze base material by removing plating mechanically was not successful and chemical techniques will be employed to better analyze base material composition and interface between plating and base material.

2. Analysis of gold plating quality.

   a. Thickness control and uniformity is under study by obtaining cross-sections of parts. ----No results as yet.

   b. Surface impurities by infra-red analysis. Data obtained by M&P Laboratory.

      Organic Material Concentrations

Vendor	ppm.
A	17
B	9

      Again, positive identification of type of organics was not pursued due to small quantities found.

3. Line processing and part performance review.

   a. Effectiveness of line cleaning:

      Check of organic material after line cleaning resulted in the following:

Vendor	ppm.
A	2.1 or less
B	3.6 or less

4. Alteration of part or process drawings to improve quality.

   None, at this time since processes seem to be very effective up to the point of our investigation.

E. Conclusions

Cap-

Material meets or exceeds drawing specifications regarding chemical composition and due to the cleaning processes organic contamination is all but eliminated.

Preform-

Material composition meets drawing specifications.

Header-

Effectiveness of line cleaning processes regarding organic contamination seems to indicate this is not a problem area. However, more work is necessary to further identify composition and nature of apparent differences of gold quality.

Estimate of portion of work complete is 20%.

F. Program for next Quarter

Cap-

Complete the analysis of sections of base material.

Preform-

Complete the analysis on the effectiveness of cleaning processes.

Header-

Since work in this area has essentially just begun, more information regarding gold quality will be obtained together with comparison of solderability of gold to pellet and header (Both Vendors).

VII. AREA OF WORK - INTERCONNECTIONS.

1 A. Work Item - Improve Bonding Process (LANZL, DURSO, RICHARDSON, R. E. SMITH).

B. Abstract - 1. Header bonding: Bending of the posts has proven advantageous in reducing the number of open leads on this unit. The posts are now being bent on a post bending fixture in the Device Fabrication area. Investigation has been made for procuring headers with posts bent and flattened.

2. Increased pellet bond area: Bonding the lead wire in two places on the pellet has increased reliability of this unit by reducing the number of opens due to leads lifting off pellet on high temperature storage tests.

3. Wire quality and specifications are being studied to determine the necessary inspection and test procedures to assure reproducible control over incoming material.

C. Purpose - 1. The purpose of work performed was to investigate the feasibility of procuring headers with bent, flattened posts, and to minimize the number of failures due to the lead wire lifting off the pellet.

2. To improve incoming quality control for bonding wire.

D. Narrative and Data 1. Header bonding and increased pellet bond area: Vendors were contacted to quote on costs to bend and flatten the header posts. Quotes received were:

a. To have posts bent 90° - 5% increase in basic header cost.
b. To have posts bent 90° and flattened - 10% increase in basic header cost.

Upon review of the Production Schedule and the above additional costs, it was decided to do the post bending in the Device Fabrication area as a day work operation. The present device bending equipment has a capacity for approximately 800/hour.

Failures due to opens have decreased from 33% to 3%. This decrease has been due to post bending, more concentrated gas coverage, better TCB methods and operator training. Better TCB methods include slack in wire, wire positioning, bonding the wire in two places on the pellet, and hold-down time of three seconds.

The contribution of two bonds on each lead on the pellet while beneficial, is hard to evaluate.

However, analyses of failures occurring on high temperature storage tests show the following results:

Lot sample size - 25 units

Single bond on Pellet	Double bond on Pellet
10 opens/6 lot samples	1 open/6 lot sample

The double bond process was under preliminary evaluation during the first work period and inadvertently omitted as part of the program for this quarter. Conversion to this method of bonding occurred at the boginning of this quarter and will now be referred to as the "standard" process.

2. Evaluation of bonding wire:

   a. Wire quality is under study because present vendor's problem of supplying consistent annealed material. A check of incoming inspection has indicated several rejections of material for variations in mechanical properties. Several areas are affected by this situation and are listed as follows.

      1. Due to observed variations in temper of wire a precautionary re-annealling process was necessary to maintain uniform quality of wire used on line. Therefore, drawing specifications are under study so that they will be more representative of the final part that is used in the device.

      2. Area of elongation measurement seems to be in conflict between vendor and laboratory. Standardization of gage length and procedures are necessary to obtain comparable data for use in changing specifications.

      3. Investigation of easier, faster, and more accurate determination of the important physical properties which effect bond strength and thus improve general quality of lead attachment.

      4. Effect of grain size upon temper of gold wire and thus bond strength to pellet.

   b. Spectrographic analysis of .002" gold wire: % By Weight.

	Spec.	Estimated Actual Analysis
Au , Min.	99.99	99.9961
Ca., Max.	0.0003	0.0003
Cu., Max.	0.002	0.001
Fe., Max.	0.002	0.0004
Pb., Max.	0.0001	-
Mg., Max.	0.002	-
Pd., Max.	0.001	-
Pt., Max.	0.001	-
Si., Max.	0.0001	0.0008
Ag., Max.	0.005	0.001
Ni	-	0.0002
Al	-	0.0002
Total Max. Impurities	0.010	

c. Surface Contamination by infra-red spectrophotometric analysis of as received material:

1.09 grams of wire extracted resulted in organic material present in Order of Magnitude of 23 $\pm$ 10 ppm.

d. Effectiveness of line cleaning:

Work being processed on line results not obtainable at time report compiled.

e. Second source to supply wire:

A second supplier has submitted samples with varying tempers, detailed data and history of each lot for experimental production evaluation.

E. Conclusions

Comparison of production schedule and additional costs to bend and flatten header indicate that post bending should be done on existing equipment in Device Fabrication area.

Reliability test results indicate that failures due to open leads off pellets have been drastically decreased with application of two bonds per lead on the pellet.

Evaluation of bonding wire, based on preliminary data, indicates more effective test procedures are necessary to properly control incoming bonding wire at Acceptance Quality Control.

F. Program for next Quater

Work will be directed in improving the existing post bending equipment and developing more efficient post bender methods. Evaluation will continue of the double-bond on the pellet by analyzing failures on

VIII. AREA OF WORK - RELIABILITY MEASUREMENT (T. E. JACOBS).

1 A. **Work Item** - Continuance of Phase I Series of Step Stresses; Plan for Phase II Series of Step Stresses.

B. **Abstract** - All stresses complete, except for the 92 and 192 hour/step 45V + temperature stresses. These two stresses may have to be discontinued to provide space for the Phase II Stresses which should be started earlier than originally planned because of the desirability of a 192 hour/step in Phase II.

Present plans call for the Phase II Stresses to be patterned after the Phase I Stresses except that in most cases the 1 and 4 hour stresses will be deleted and a 192 hour/step added.

C. **Purpose** - The step stress tests will -

a. Point out failure mechanisms existing in the device.

b. Provide a measure of the ultimate capabilities of the device.

c. Provide guidance on the selection of conditions to be used in the fixed stress life tests conducted later in the program.

D. **Narrative and Data**

1. Results on Phase I Step Stress

Figures 1 and 2 present the latest data. The results are generally disappointing as the short-time high stress failures occur at or near the eutectic temperature (380°C) of the contact material· the effectiveness of step stressing is lost unless large numbers of failures are created over a span of steps. The failures shown in f, ("Temperature Step + V_{CB} in avalanche") while encouraging are probably not valid since device oscillation was uncovered when the test was close to completion. The test can not be repeated until Phase II due to lack of facilities, but it was found that the oscillation could be eliminated on many devices by back biasing the EB junction. The Phase II avalanche test will incorporate this back bias.

However, there are some indications that a valid step stress program will materialise: both the temperature step stress + V_{CB} = 45V, and the power step stress at V_{CB} = 20V tend to show a time for failure dependent on a time for step vs. stress intensity relationship. For example, test "b" devices fail earlier on the 192 hour/step sequence

than on 20 hour/step. But since this relationship appears to develop over the longer step times (4 or 20 to 192 hour/step), the Phase II tests will include a 192 hour/step sequence, and will omit some of the shorter times.
It would perhaps be desirable from the standpoint of information gained to institute a 500 hour/step test: however, such a test would probably not have any practical use: it is too long for use in burning or screening.
Note that large numbers of failures occur at the 380°C point in temperature stress and the 1.9 Watt point in the .25 amp + power stress. These failures are believed caused by stressing beyond the designed-in capabilities of the device: in most cases, reject analysis shows that the 377°C gold-silicon eutectic was exceeded.
Both in tests "d" and "e" there is some inconsistency in the apparent power required to generate this 377°C temperature. This was due to problems in setting and maintaining the emitter current and the low voltage on the collector, so that in some cases the correct power was not supplied to the device.

2. Plan for Phase II Series of Step Stresses

The Phase II Series of Step Stresses will commence in December. Prior to their submission to these stresses the devices shall be subjected to screening stresses similar to the step stresses themselves. Product improvement will therefore reflect improvements in process plus ability to screen out potential failures. Screening stresses contemplated include a centrifuge test and a 45V + temperature test. Also, for the final series of life tests (Item IIE on the work schedule), an avalanche voltage + temperature test may be instituted as a screen, depending on results shown by the avalanche test included in Phase II Step Stressing.

The tests now planned for Phase II Step Stress are as follows: (20 devices per time sequence).

a. Temperature step stress - 92 and 192 hours/step.

b. Temperature step stress +45V -4, 20, 92, 192 hours/step.

c. Power step + (V_{CB}=20V) -4, 20, 92, 192 hours/step.

d. Power step at (I_C = .5 amp) -20, 92, 192 hours/step.

e. Power step at (I_C = .25 amp), 5 minute on/ 5 minute off cycle - 20, 92, 192 hours/step.

f. Temperature + V_{CB} in avalanche at 2 ma, and back biased EB junction-20 hours/step.

g. Constant acceleration (4 orientations) 10, 20, 40, 100 KG - 50 devices.

h. Vibration fatigue 50 G; 100 to 2000 cps sweep, 1 hour cycle; 1 cycle/orientation; 3 orientations. Then same except 5 cycles per orientation.

E. Conclusions

The step stress tests have thus far proven largely ineffective in the function for which they were designed, namely, creating large numbers of failures under the assumption of a relationship between stress level and time to failure. However, an upward extension of the time sequence to 192 hours/step in Phase II may uncover something.

F. Program for next Quarter

Step Stress Phase II series will be started. Results from this and the prior series will be used to plan for the long term life test conditions.

FIGURE 1.

Table Showing Cumulative Failures.

STRESS	Hrs/ Step	No. of Units.	Temperature in °C.									
			300	320	340	360	380					
a. Temperature Step Stress	1	20	0	0	0	0	20					
	4	20	0	0	1	1	20					
	20	20	0	0	0	0	20					
	92	20	0	0	0	1	20					
	192	20										

	Hrs/ Step	No. of Units.	Temperature in °C.									
			200	220	240	260	270	280	290	300	310	320
b. Temperature Step Stress + V_{CB} = 45 V	1	20	0	0	0	0	0	0	0	0	0	0
	4	20	0	0	0	0	1	1	1	1	1/19	1/18
	20	20	0	0	1	1	1	1	1	1/19	2/19	3/19
	92	20	0	0	0							
	192	20	1	1	2							

	Hrs/ Step	No. of Units.	Power in Watts									
			1.0	1.25	1.5	1.7	1.8	1.9	2.0	2.1	2.2	2.3
c. Power Step at V_{CB} = 20 V	1	20	0	0	0	0	X	X	0			
	4	20	0	0	0	0	0	0	0			
	20	20	0	0	1	1	1	1	1			
	92	20	0	1	2	2	2	2	3			
	X = These Stresses were missed.											

	Hrs/ Step	No. of Units	Power in Watts									
			1	1.25	1.5	1.7	1.8	1.9	2			
d. Power Step at I_C = 0.5 Amp.	1	20	0	0	0	9	10	20				
	4	20	0	0	0	0	0	10	17			
	20	20	0	0	17/19	[illegible]/19						
	92	20	0	0	20							

	Hrs/ Step	No. of Units.	Power in Watts									
			0.5	0.75	1.0	1.25	1.5	1.7	1.8	1.9	2.0	
e. Power Step at I_C = 0.25 Amp. 5 Min. ON, 5 Min. OFF Cycle	1	20	0	0	0	0	0	1	1	2	13	
	4	20	0	0	0	0	0	0	0/19	13/19	17/19	
	20	20	0	0	0	0	0	2	4	7	18	
	92	20	0	0	0	2						

	Hrs/ Step	No. of Units	Temperature in °C.									
			50	100	150	200	225	250	275	300		
f. Temperature Step with V_{CB} in Avalanche at 2 ma.	20	20	1	1	3	9	11	13	15	16		

Figure 2.

Table Showing Cumulative Failures

Work Item and Sample	Plan		Cumulative Failures
a. Thermal Shock/Humidity	10 cycles 100°C. Water to 0°C. Water; then Humidity (per MILS 19500B, para. 40.G): then		0
50 Units	10 cycles 300°C. Molten Solder to -65°C. Toulene and dry ice, followed by Humidity (per MILS 19500B, para. 40.G)		1
b. Constant Acceleration	20,000 G	Z_1	1
		X_1	2
50 Units		Y_1	4
		Y_2	6
	then		
	30,000 G	Z_1	8
		X_1	8
		Y_1	11
		Y_2	15
c. Mechanical Shock	1,500 G; 4 Orientations, 5 blows/ orientation		0
	then		
50 Units	3,000 G: 4 Orientations, 5 blows/ orientation		1
d. Vibration Fatigue	20 G; 100 cps.; 3 Orientations, 32 hours/orientation		0
	then		
50 Units	50 G: Sweep 100 cps. to 2,000 cps.; 1-hour cycle; 1 cycle/orientation; 3 orientations		After 2 Hours 1 Failure After Completion 3 Failures

IX. AREA OF WORK - FAILURE ANALYSIS (A. POE).

1 A. Work Item - Failure Analysis

B. Abstract - A large number of units which had failed during the step stress tests were subjected to failure analysis procedures. In most cases, the units had failed under stress levels far beyond their normally rated values.

The behavior pattern developing is as follows:

1. Under high temperatures, our devices were highly resistant to any degradation. Longer period stresses at high, better controlled temperatures, are planned to further test such items as bond adherence, resistance and pellet bond degradation.

2. Stresses under very high voltages and temperatures produced some surface type degradations. Closer line control is expected to reduce these failure rates.

3. Stresses under conditions of high power, low voltage and high current resulted primarily in thermal destruction of the devices at power levels twice normal. Future tests of longer duration but at somewhat lower levels may be of advantage in detection of internal junction defects.

4 Results of the initial mechanical tests were below expectation but improvements in bonding techniques and the header are expected to show considerable improvement

C. Purpose - Based on studies being made of the failure mechanisms, both in the previously defined step stress program and standard life tests the directions of process improvement can be established and action can be taken to eliminate the contributing mechanisms. The effect of these process improvements can then be determined by constant monitoring of the failure rates.

D. Narrative and Data - Analysis of tests being performed

1. Temperature Step Stress - In general, units on test held up without significant changes in parameters until a temperature exceeding the theoretical thermal limitation of the device had been reached. Most of the devices then failed abruptly in a similar manner.

The most vulnerable point of the transistor from the thermal point of view was the Base-gold wire connection to the aluminized ring contact. Since the Au-Si eutectic is given at 370°C., one may expect the presence of a liquid phase at this temperature. The aluminum makes a ternary system with a liquid phase at a slightly lower temperature. At 380°C., therefore, it was not surprising that gold alloyed first into the Al-Si phase working its way clear around the ring in most cases and then penetrated the Silicon metal until it reached or crossed the CB or EB junctions. The depletion of gold from the base bond due to extensive alloying into the Aluminum and Silicon eventually caused it to melt off, leaving a stub of intermetallic material in many cases. This type of open will be designated as Type fV

For units subjected to 380°C. for 4 hours and longer, the pellets were found to be loose from their mountings so that they could be readily broken off by sideways pressure. A liquid phase developing at this point can be expected to deteriorate the bond.

The data below indicates this is highly dependent on the time dwell at high temperatures. In no case is the CB junction believed to have shorted by gold penetrating up from the collector bond.

A summary of all failure modes seen is presented.

	Shorts			**Opens**		**Type G**	
	Type C	D	E	Type f-V	Other	Pellet	Loose
20 Units - 1 hr. to 380°C.	20	17	16	5		1	
19 Units - 4 hrs. to 380°C	19	19	18	7		14	
1 Unit to 340°C.					E(f-I)		
20 Units - 20 hrs. to 380°C	17	17	10	6		19	
20 Units - 92 hrs. to 380°C.	20	20	20	12		19	

The 20-hour series appeared to be run at a slightly lower temperature than the other tests judging from the physical appearance of the units. Note also that 3 units had all junctions still undamaged and 10 units still had good diodes. Closer temperature controls are planned for future runs as a result. Only one unit opened up below 380° due to a bond defect.

Contact resistances V_{CE} and V_{BE} sat. did not appreciably increase even on the 92 hour step test up to the failure point indicating pellet loosening was not appreciable prior to failure.

In general, the units held up better than could here been predicted.

2. Temperature Step Stress + V_{CB} 45V.
Temperature Step Stress with V_{CB} in Avalanche at 2 ma.

Both of these tests will be discussed together as they are both designed primarily to produce extremely rigorous stresses on the CB junctions. The combination of high voltage and temperature will create surface inversions with resulting I_{CBO} degradations.

Only 2 units have been received from the 45V test while as many as 16 failed the higher voltage Avalanche condition. However, visual examination of 6 of the latter rejects show them to be "blasted" by a high power condition. The previous report indicated that the Avalanche test rack being used was found to have uncontrolled AC surges. This condition could readily have resulted in destructive current levels thru the units. The other rejects in this lot appear to be surface type failures (Type A) although the stress level and time to failure may have been accelerated by the rack difficulties.

Summary of Failure Modes

Test Point & T_j	No. of Fails	Failure
45V - 240°C	1	Type f-II - Open Base
320°C	1	Type (a)

	No. of Units	Failure Modes	Est. T_j °C	Notes
Avalanche +				
200°C	9	7-type (a) 1-type (d)* 1-type (c)*	260	*6 units exhibiting dead short conditions or having base leads blasted may have failed due to Rack condition.
225°C	2	1-type (a) 1-type (c)*	285	
250°C	2	1-type (a) 1-type (b)	310	9 units exhibit recoverable surface type I_{CBO} characteristics - Type (a)
275°C	2	2 type (c)*	335	
300°C	1	1-type (c)*	360	

Type (a) units coming off the Avalanche test rack were found to exhibit a somewhat unexpected I_{CE} V_{CB} characteristic in that the current rises steeply in a convex upward manner at voltages between 10-30 volts rather than starting to rise steeply at the origin.

Another peculiarity is that low voltage C_{ob} measurements are lower on the reject devices than on devices after recovery by heating. The usual Type (a) reject has a higher C_{ob} than its recovered or original condition. Although an explanation of this difference is premature at this time, it is believed that the exceptionally high voltage application in the Avalanche condition may have isolated inversion islands on either side of the existing junction. When the depletion layer spreads into these islands at some intermediate voltage, the current rises steeply as in the normal case. Some typical data values of reject units are given:

	60V I_{CBO} Value			C_{ob} value 0.05V	
Test	Original	After Failure	After Heating	After Failure	After Heating
45V+T	4.7 na	6.3 ua.	6.0 na.	27.2 pf	25 pf
Avalanche +T	2.6 na	17 ua	2.3 na.	19.5	22.8
	1.7 na	35 ua	1.6 na.	19.1	22.0
	.9 na	730 na	2.3 na.		
				Heating @ $300^{o}C$	- 2 hrs

The one Type fII base open was found to have been defective bond.

A more accurate statistical appraisal of unit performance on Avalanche Stress will be available as a result of Phase II testing.

4. Power Step Tests - Failures for the most part were due to the thermal limiting of the devices and are characterized by heavily alloyed Emitter regions, where most of the power dissipation took place. Physically these units appeared to have undergone localized emitter temperatures in excess of $380^{o}C$. In many cases, enough gold had penetrated into the emitter regions to cause destructive erosion of the gold emitter wire (Type fV open). Most units are characterized as Type c, d and e shorts.

A few units which failed at lower power levels than the majority are described as follows:

	Stress Pt Failed	Failure Analysis
Power Test	20 hr. at 1.5 Watts	Typical Type (a)
@20 V_{CB}	92 hr. at 1.25 Watts	Typical Type (a)
	92 hr. at 1.5 Watt	Open Base - Type fI
	92 hr. at 2.0 Watt	CE short - Type (d)

The units stressed at low voltages and high current levels (0.25A and 0.5A) failed as Type c, d, or e shorts. The voltages involved (8V 2.0 Watt) are apparently too low to stress the CB junction in such a way as to produce Type (a) rejects — However, heating effects possibly coupled with internal junction defects may produce early failures.

Units will be run at longer time periods during Phase II to weed out internal defect types more readily if failures occur at relatively low power levels.

In general, units withstood low voltage power conditions (much higher than rated) with relatively little difficulty.

5. Mechanical Tests 20 and 30 KG Centrifuge - Two units reported as failures in the previous report were found to be intact on analysis. All rejects are of the open type and are catagorized below. One new type of open was encountered here which was not previously described to be classified as Type fVI. This involves a wire which upon opening, tears out a piece of Silicon adhering to the wire. This condition takes place if adhesion of all elements is good but the unit stress, due to excess wire weight, excessively heavy shock, or insufficient adhesion area, exceeds the strength of the Silicon. The sharp angle the lead makes with the surface is the most vulnerable point for this to take place due to the "notch" effect. A type fVI failure is also possible if excessive bonding pressures have pre-cracked the Silicon under the bond.

Classification of Rejects

Test	Type f II	Type f III	Type f VI
20 KG	2	1	2
30 KG	0	5	4

FAILURE ANALYSIS.

TYPE OF REJECT.	DESCRIPTION.
a.	High leakage current, recoverable by heating.
b.	High leakage current, usually with "soft" breakdown.
c.	Collector - to - base short.
d.	Collector - to - emitter short, or very low voltage.
e.	Emitter - to - base short.
f.	Open.
f. I	Wires off pellet - Intermetallic.
f. II	Wires off pellet - Alloying.
f. III	Broken wire.
f. IV	Open at Header Post.
f. V	Wires melted.
f. VI	Wires torn from pellet.

PROFESSIONAL PERSONNEL

and

TOTAL APPLIED EFFORT

for period covering

31 July 1962 - 31 October 1962

Personnel	Manhours
Dr. A. R. DiPietro	4,110 total
J. L. Durso	
F. K. Glasbrenner	
T. E. Jacobs	
R. T. Kobler	
R. H. Lanzl	
C. E. Logan	
J. C. Richardson	
R. E. Smith	
J. F. Wholey	
A. Poe	

U. S. ARMY ELECTRONICS MATERIEL AGENCY.

Production Engineering Measure

DA-36-039-SC-86727

Silicon Grown Diffused Transistor

2N336

The purpose of the Production Engineering Measure Program is to improve the production techniques on the Silicon Grown Diffused Transistor type 2N336, with a maximum failure rate of .01% per 1000 hours at a 90% confidence level at 25°C as an objective.

Second Quarterly Report

31 July 1962
31 October 1962

General Electric Company
Semiconductor Products Department
Syracuse, New York

Report Prepared by: P. W. Olski
P W Olski

Approved by: J. R. McLaughlin
JMcLaughlin

TABLE OF CONTENTS

1. ABSTRACT

Passivation - The equipment procurement, installation, and debugging operations have been completed. Initial trial runs have been made and the equipment is now in production use and being further evaluated.

High Temperature Main Sealing - Equipment designs are essentially complete and the procurement phase is back on schedule.

Experimentation and Evaluation - A temperature step stress test has been completed and tabulated for twelve units.

An encapsulation experiment has been started. This experiment is directed toward optimization of the flush temperature and time during the encapsulation or main seal welding operation. Initial yields were obtained and the units are presently on life test (200°C storage and 500 MW power).

Characteristic Distribution - A production monitoring system has been established which will give a weekly distribution of all of the major and most of the minor device parameters of the devices made on the production line.

2. PURPOSE

The purpose of the Production Engineering Measure Program is to improve the production techniques on the Silicon Grown Diffused Transistor type 2N336, with a maximum failure rate of .01% per 1000 hours at a 90% confidence level at 25°C as an objective.

In the fabrication of semiconductor devices there are inevitably critical process steps which, due to process variability, exert an influence on test yields and also on long-range reliability. In order to achieve the reliability objective of this program, two key process steps have been singled out to maximize process control. By redesign of initial production equipment in these two areas, the latest processing techniques can be incorporated, while minimizing process variability, and at the same time greatly increasing production capability. The two specific work areas referred to above are Surface Passivation and High Temperature Main Sealing.

The objectives of this report are now noted.

2.1 PASSIVATION

Installation of equipment which will . . .

(1). Permit the incorporation of the latest processing techniques.

(2). Minimize process variability.

(3.) Increase production capability.

2.2 HIGH TEMPERATURE MAIN SEALING

Installation of main seal welding equipment which will meet the process requirements, defined as necessary to achieve highly reliable device performance, and which will also provide for volume production.

2.3 EXPERIMENTATION AND EVALUATION

2.3.1 Temperature Step Stress Experiment- Evaluation of cumulative failures versus junction temperature.

2.3.2 Encapsulation Experiment-Optimization of flush temperature and time for the encapsulation or main seal welding process.

2.4 Characteristic Distributions - Establishment of a system to monitor the electrical parameter distributions on the 4JD4C line where the 2N336 is produced.

3. NARRATIVE AND DATA

3.1 PASSIVATION

When the component parts for the automatic passivation system were received from the vendors they were first inspected for correctness to print specifications, then for quality of manufacture by determining that there were no apparent visual defects. The component parts were then assembled and installed on the frame of the machine.

Because of the nature of the materials involved in the passivation process, all valves, tubing, piping, and others internal surfaces had to be constructed of glass or a qualified inert material. While the materials choosen for the job were adequate from a functional viewpoint, some changes were necessary to increase the operational reliability of the system.

These changes were as follows:

1. The inlet valve was redesigned from glass to teflon to:

   (A) Eliminate contamination from the lubricant necessarily used with a glass valve.

   (B) Insure fail safe pressure tightness.

   (C) Produce a maintainence free valve.

   (D) Eliminate a potential safety hazard.

2. The raising and lowering of the system chamber was redesigned from a manual to a hydraulically operated mechanism both for safety purposes and operator convenience.

3. The inlet and outlet ports were redesigned and relocated in order to prevent physical disturbance of the devices during the passivation cycle.

4. The external environmental exhaust consisting of a welded PVC hood was enlarged in order to completely isolate the system from adjacent work areas.

After these changes were completed the debugging and trial run operations were initiated.

The first step was to determine that the process cycle was properly timed and sequential and to evaluate the mechanical functions.

Following this, simulated runs were made using an inert gas with a tracer added to determine the hermeticity of the system.

Finally, actual runs were made, but without devices, to ascertain if any major design or operational problems existed and to acclimatize the entire internal area of the system under actual use conditions. Accordingly no major design or operational problems were apparent.

This was followed by initial evaluation runs to satisfy that device yields were at least equivalent to that of the production run on the prototype equipment.

Satisfied with this, the final design automatic passivation system has been released for normal production use so that large scale evaluation of the system may be accomplished.

This will be realized by monitoring of the production monitor distributions. In addition, a reliability experiment has been designed to further evaluate the results of the new system vs. the prototype predesessor.

3.2 HIGH TEMPERATURE MAIN SEALING

The second quarter work on this phase of the contract has been concentrated on the design and procurement of the welding equipment. As reported after the first quarter, a high production rotary type welding machine has been made available and reconstruction for high temperature processing has been started.

A single station from the welding machine has been set up utilizing a bearing design conceived to meet the requirements of the process. As noted in the previous report, two bearing designs were under consideration. The design using the aluminum oxide coated bearing seat was selected. The sample station has been measured under operating conditions to determine expansion points and degree of distortion. From this study a detailed design of the welding station has been made and all stations on the welding machine have been contracted to a specialty vendor for modification.

Parts have been received to modify the purging gas control system. Purging gas temperature thermocouples and instruments have been received and installation of these items has started.

These modifications will enable the welding machine to perform the encapsulation process within the process limits of time, temperature and purge gas flow, as originally outlined for this process.

Can loading equipment designs have been studied. The selection will be made soon depending on the final purging time required immediately prior to welding. Long purge times will allow time for hand loading thus making can loading equipment impractical.

3.3 EXPERIMENTATION AND EVALUATION

3.3.1 Temperature Step Stress Test

Fourteen units were sent to the Signal Corps for temperature step stress evaluation. We have tested twelve units from the same lot using the same failure criteria in order to obtain correlation with your results.

The following operating conditions were observed:

(1) Two hour storage at the specified temperature.

(2) The units were read after a minimum of one hour cooling.

(3) The units were stored at the next highest temperature after the completion of the readouts. (The units were read at room temperature, 250°C, and at 300°C with 15°C temperature increments thereafter.

The following failure criteria were observed.

(1) I_{CBO} @ 15 V $\geq$ 2 ua

(2) H_{fe} @ 6V, 2 MA ΔH_{fe} = -50%.

Upon examination of the data only one Δ H_{fe} failure is found and this occurs at 315°C. All other failures occur at a temperature of 345°C or higher and are primarily I_{CBO} failures.

The following test equipment was used.

(1) h_{fe} read on Tektronix Type 575 scope.

(2) I_{CBO} read on Kiethly model 410 micromicroammeter.

TABLE 3.3.1-1

2N336 TEMPERATURE STEP STRESSED DEVICE

OPERATING CONDITIONS

1. 2 HR. STORAGE AT SPECIFIED TEMP.
2. 1 HR. COOLING, THEN READ UNITS
3. PROCEED TO NEXT HIGHEST TEMP.

FAILURE DEFINITION

1. I_{CBO} @ 15V $\geq$ 2 μA
2. H_{FE} @ 6V, 2 MA $\Delta H_{FE} = -50\%$

NOTE:

I_{CBO} - MEASURED IN μμA

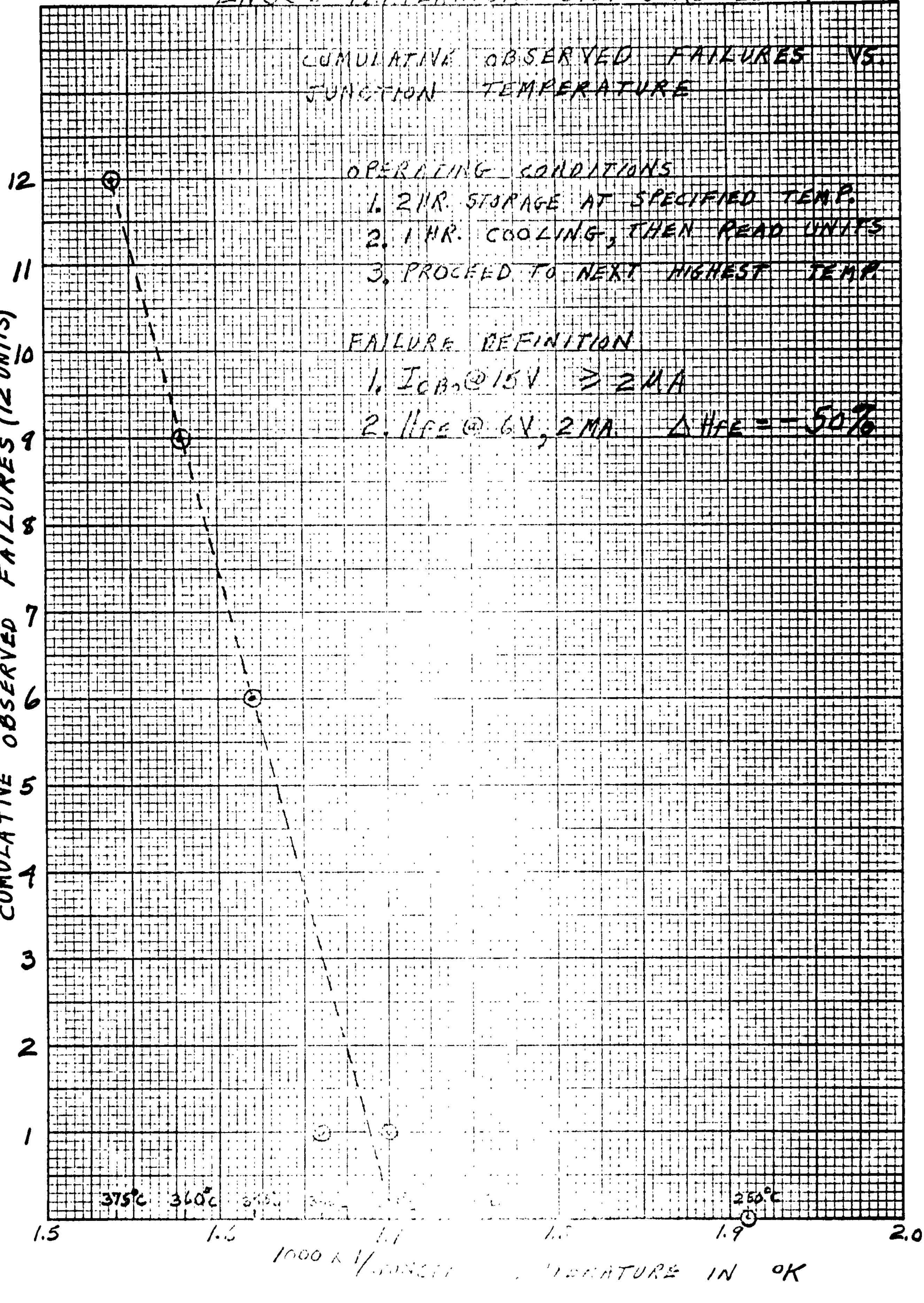
* - DENOTES FAILURE

UNIT #

		16	17	18	19	20	21	23	25	26	27	28	29
INITIAL	H_{FE}	111.	160.	280.	89.	117.5	143.	188.	108.	87.5	100.	81.	137.
	I_{CBO}	4.0	1.7	.053	16.	3.1	15.0	5.2	23.	70.	86.	31.	5.4
250°C	H_{FE}	111.	166.5	200.	91.	125.	153.5	204.	133.	88.2	100.	92.8	135.8
	I_{CBO}	4.0	7.7	1.2	31.	4.0	27.0	5.7	90.	120.	88.	55.	7.2
300°C	H_{FE}	134.	185.	163.	116.5	133.	194.	211.	145.	102.	133.	153.	147.
	I_{CBO}	3.2	9.4	12.	79.	12.	7.6	6.0	84.	38.	3.0	110.	7.9
315°C	H_{FE}	151.8	182.	135.8*	109.	148.5	225.	204.	106.5	119.	140.	178.	165.
	I_{CBO}	2.8	6.7	34.	45.	22.	6.1	8.6	110.	40.	3.0	94.	6.4
330°C	H_{FE}	157.	182.		98.	174.5	307.	188.	98.	134.	136.	178.5	175.
	I_{CBO}	3.3	11.5		38.	37.	6.2	13.	94.	65.	2.8	71.	6.5
345°C	H_{FE}	240.	—*		105.*	—*	—*	216.	220.	194.	151.8	238.	203.
	I_{CBO}	6.9	400.μA*		15.μA*	1.MA*	>1.MA*	14.	8.9μA*	140.	2.8	56.	4.8
360°C	H_{FE}	—*						396.		—*	198.	—*	284.
	I_{CBO}	>1.MA*						340.		>1.MA*	2.9	>1.MA*	4.8
375°C	H_{FE}							—*			—*		—*
	I_{CBO}							>1.MA*			>1.MA*		>1.MA*

FIGURE 3.3.1-1

2N336 TEMPERATURE STEP STRESSED DEVICE



3.3.2 ENCAPSULATION EXPERIMENT

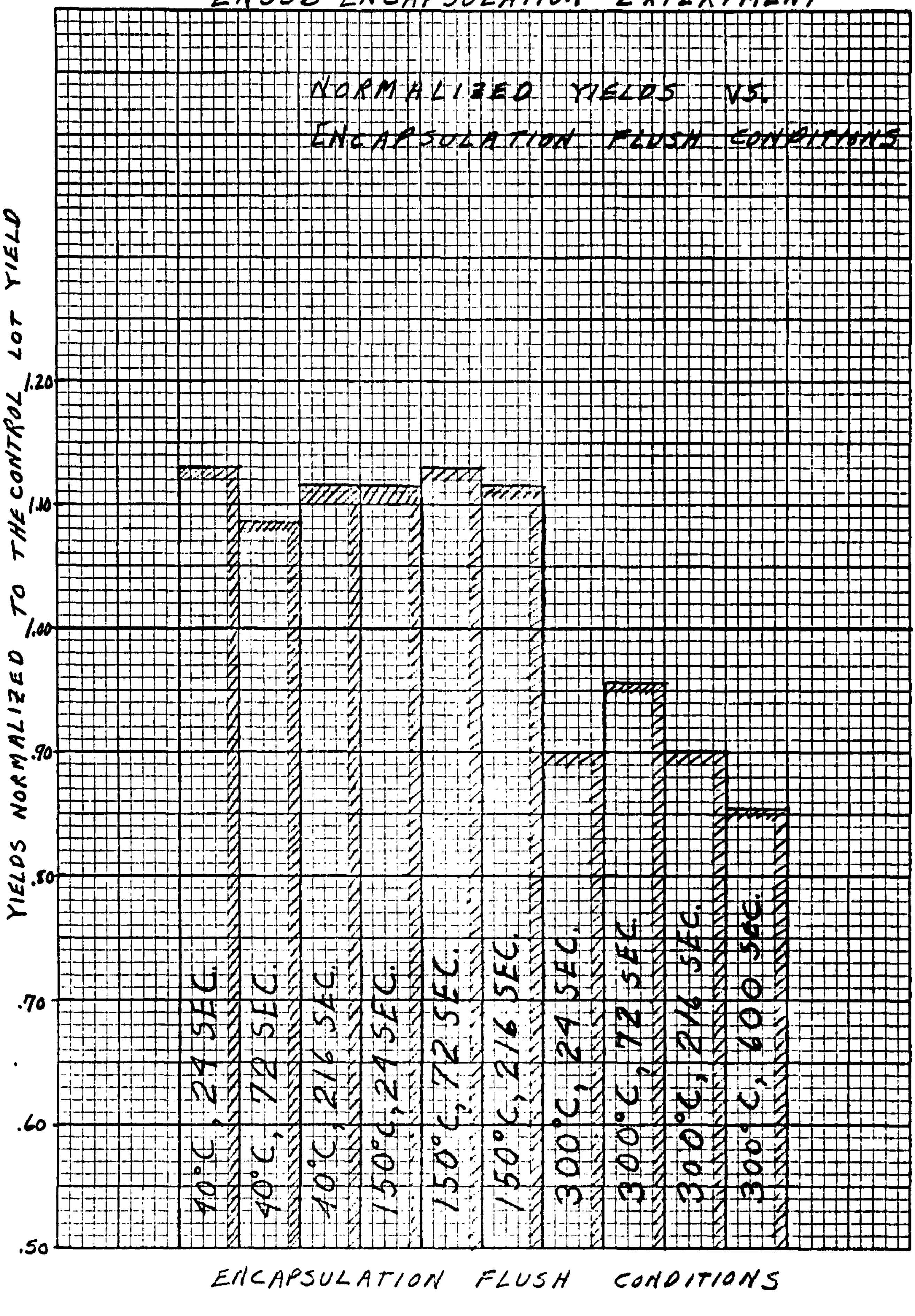
The purpose of this experiment is to optimize the High Temperature Main Sealing process. Eleven various capping conditions were used to produce 11 lots @ 80 units per lot. Keeping in mind the capabilities of the 20 station indexing type welding machine, a spectrum of various flushing temperatures and times were chosen. A control lot using the standard process was also run in order to monitor the experiment (a description of the standard process can be found in the First Quarterly Report).

The following capping conditions were run:

(1) Controls
(2) 40°C, 24 SEC.
(3) 40°C, 72 SEC.
(4) 40°C, 216 SEC.
(5) 150°C, 24 SEC.
(6) 150°C, 72 SEC.
(7) 150°C, 216 SEC.
(8) 300°C, 24 SEC.
(9) 300°C, 72 SEC.
(10) 300°C, 216 SEC.
(11) 300°C, 600 SEC.

The units have been capped, screened, and are presently on life test. Yield information was obtained after a normal aging cycle. The 40°C and 150°C flush temperatures produced about a 110% yield when normalized to the control lot yield. The 300°C flush temperature produced a 90% yield after normalization.

FIGURE 3.3.2-1
2N336 ENCAPSULATION EXPERIMENT



3.4 CHARACTERISTIC DISTRIBUTIONS

Semiconductor Products Dept. has a comprehensive system for monitoring electrical parameter distribution on the 4JD4C line. The 2N336 device is produced on this line. The relative distribution of 2N332, 2N333, 2N335, 2N336 devices produced can be changed significantly by certain techniques. However, the line can be controlled by taking a random sample of raw line (untested) units even though the distribution varies. A sample of raw line units is drawn from every shift. These units are partially aged and then certain key parameters are read out. These daily samples are then aged for the balance of the normal aging period, classified into 2N332, 2N333, 2N335, 2N336 types and tested for a number of other parameters.

In the attached report BV_{EBO}, BV_{CBO}, h_{fe}, I_{CO} 30V, 25°C data is from raw units and all other from classified units. -55°C h_{fe} will be included in the next report. There are 2 substitutions for 19500/37A Group A parameters, ie.

(1) h_{fe} instead of h_{fb}

(2) BV_{EBO}, I_E = 100 ua for I_{EBO} at 1 Volt, max. 100 ua.

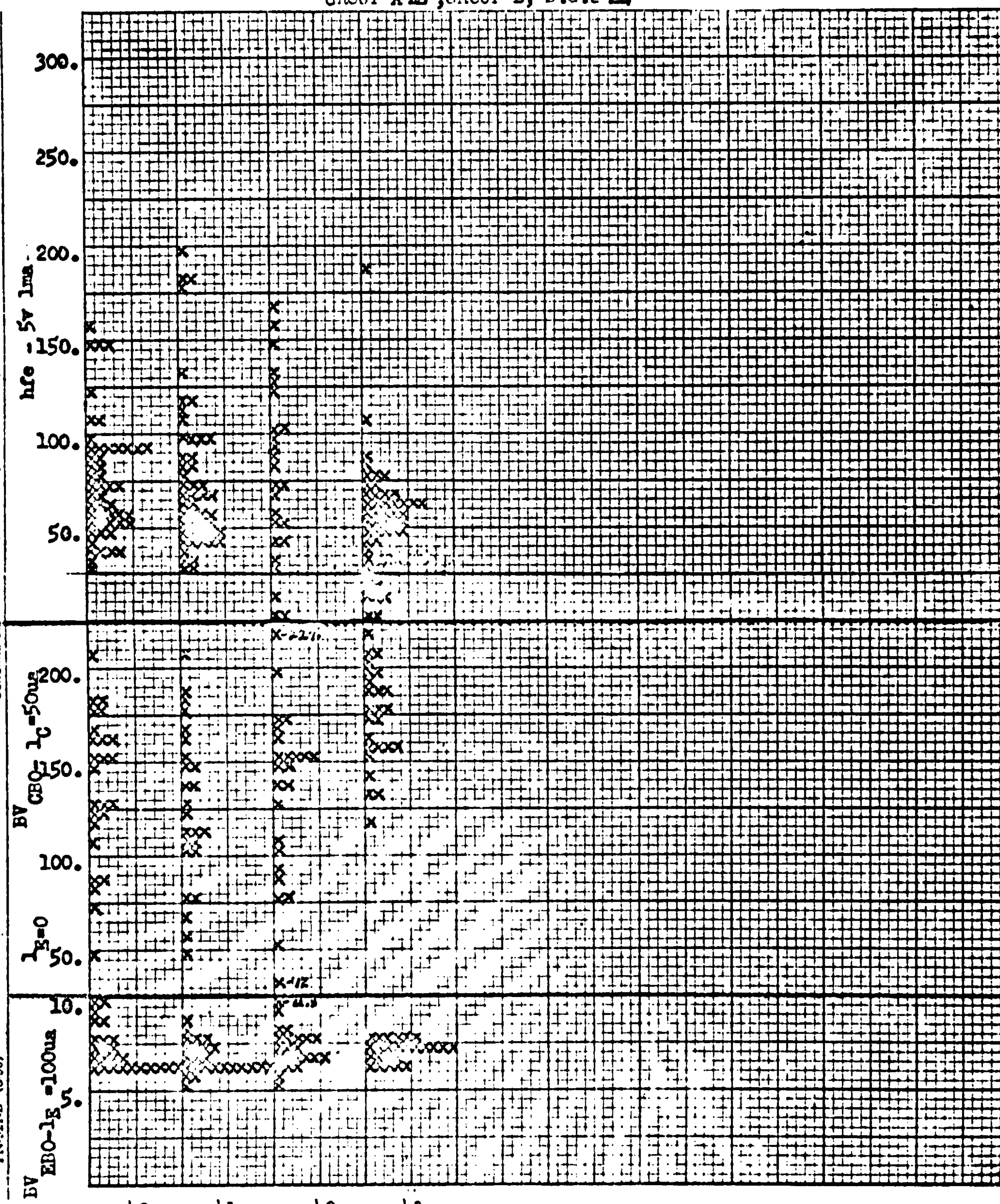
In future reports h_{rb} data will be segregated by type. Sample size and frequency will be varied as control needs dictate. For instance, C_{ob} may be put on a skip lot basis. Parameters will be added as necessary or dropped if it is found that they can be controlled via correlation with other parameters.

PARAMETER DISTRIBUTION BY WEEK

1962 - 4JD4C LINE, (2N332,2N333,2N335,2N336)

ELECTRICAL MEASUREMENTS FOR MILT 19500/37A

GROUP A ☑, GROUP B, S.G.2 ☐

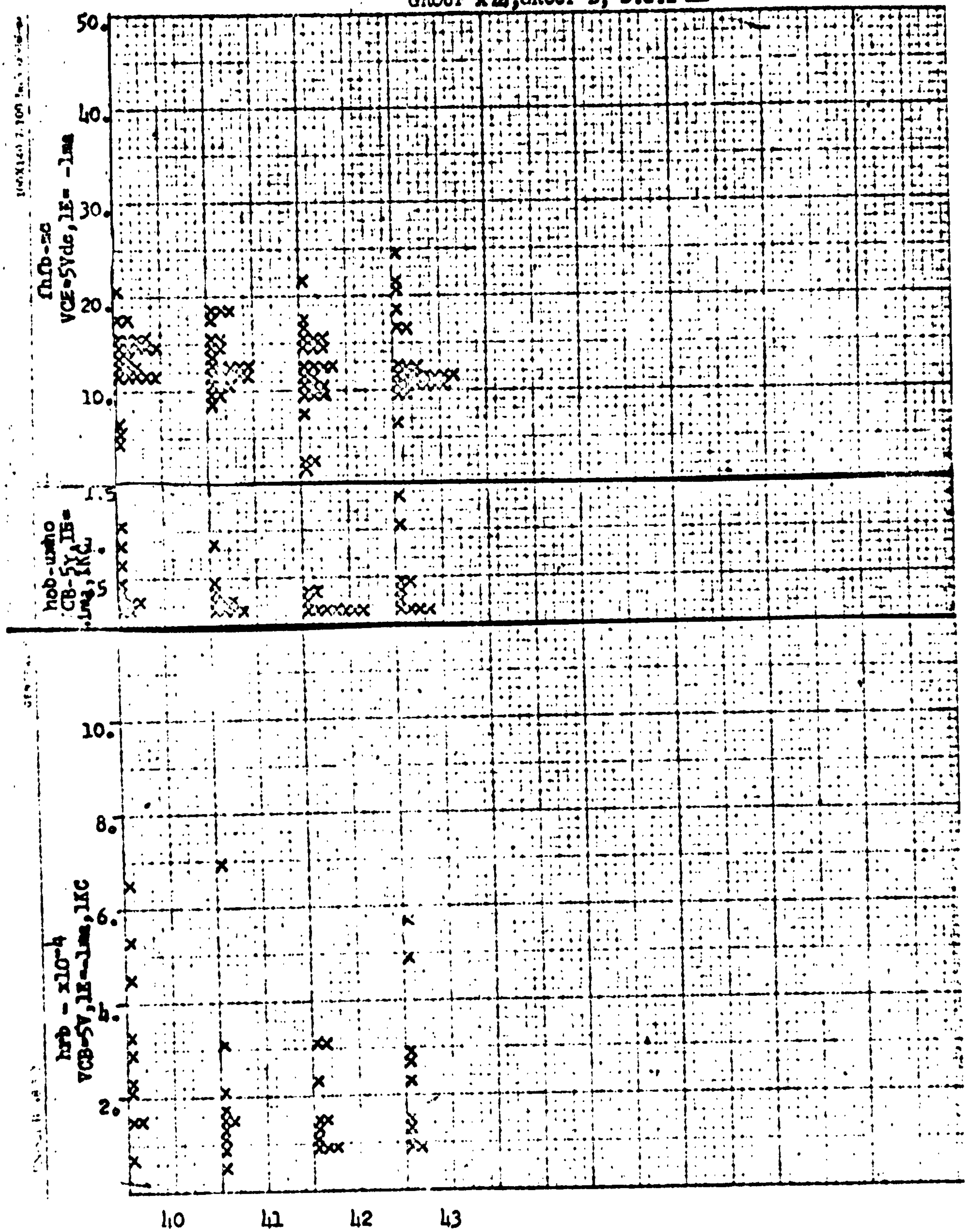


PARAMETER DISTRIBUTION BY WEEK

1962 - 4JDLC LINE, (2N332,2N333,2N335,2N336)

ELECTRICAL MEASUREMENTS PER MILT 19500/37A

GROUP A ☑, GROUP B, S.O.2 ☐



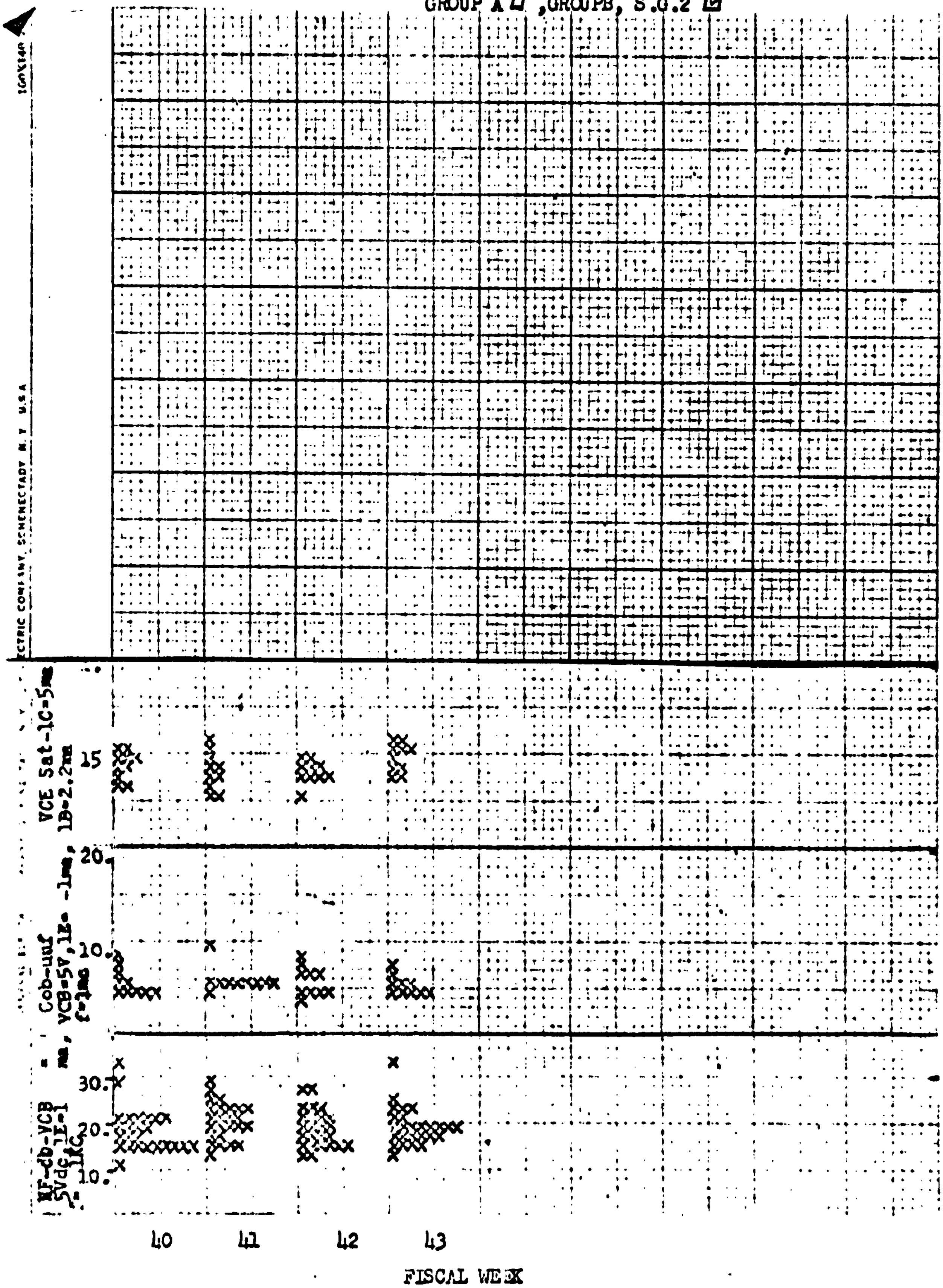
FISCAL WEEK

PARAMETER DISTRIBUTION BY WEEK

1962 - 4JD4C LINE, (2N332,2N333,2N335,2N336)

ELECTRICAL MEASUREMENTS PER MILT 19500/37A

GROUP A ☐ ,GROUPB, S.G.2 ☑

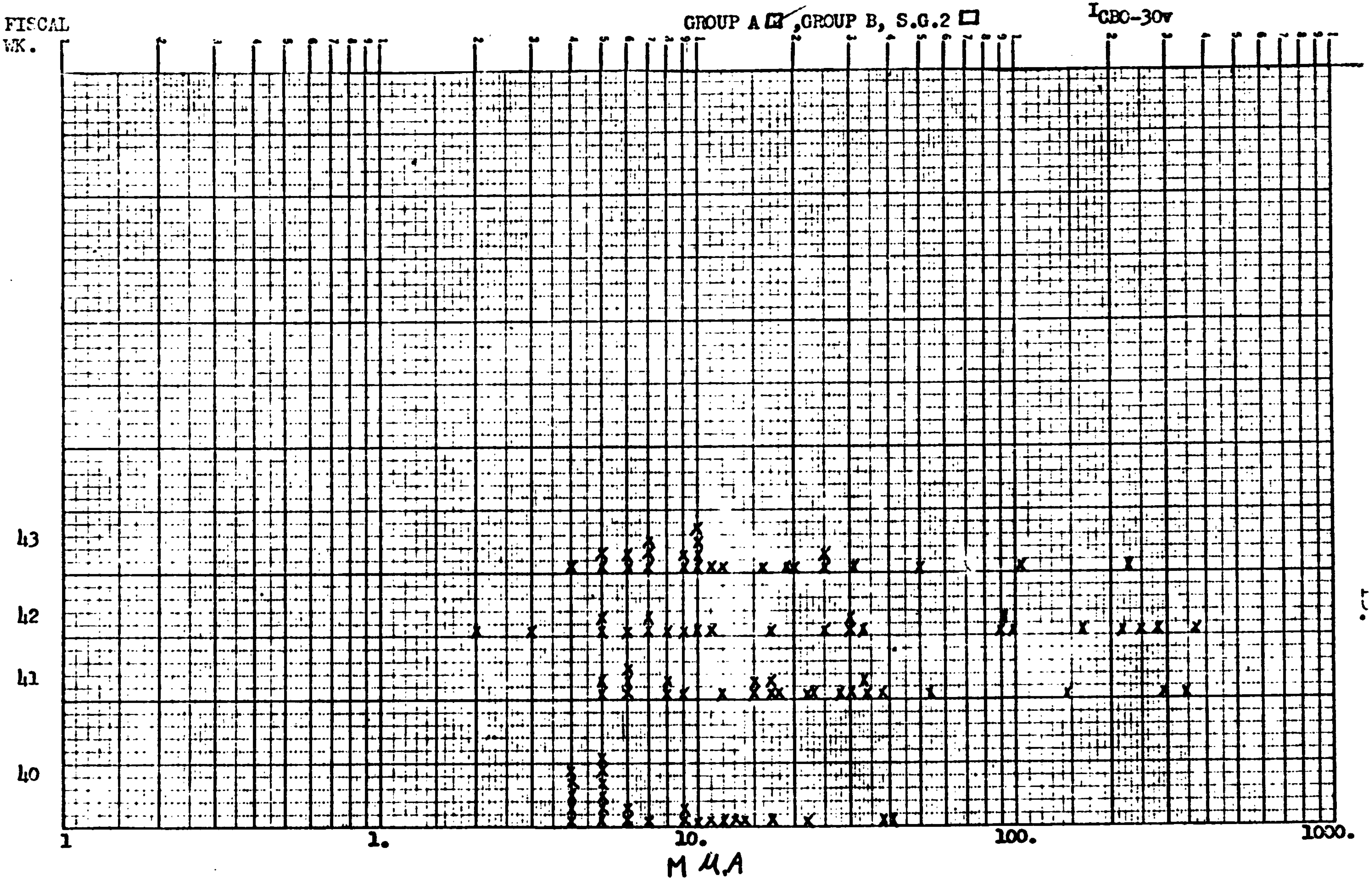


PARAMETER DISTRIBUTION BY WEEK

1962 - 4JD4C LINE, (2N332,2N333,2N335,2N336)

ELECTRICAL MEASUREMENTS PER MILT 19500/37A

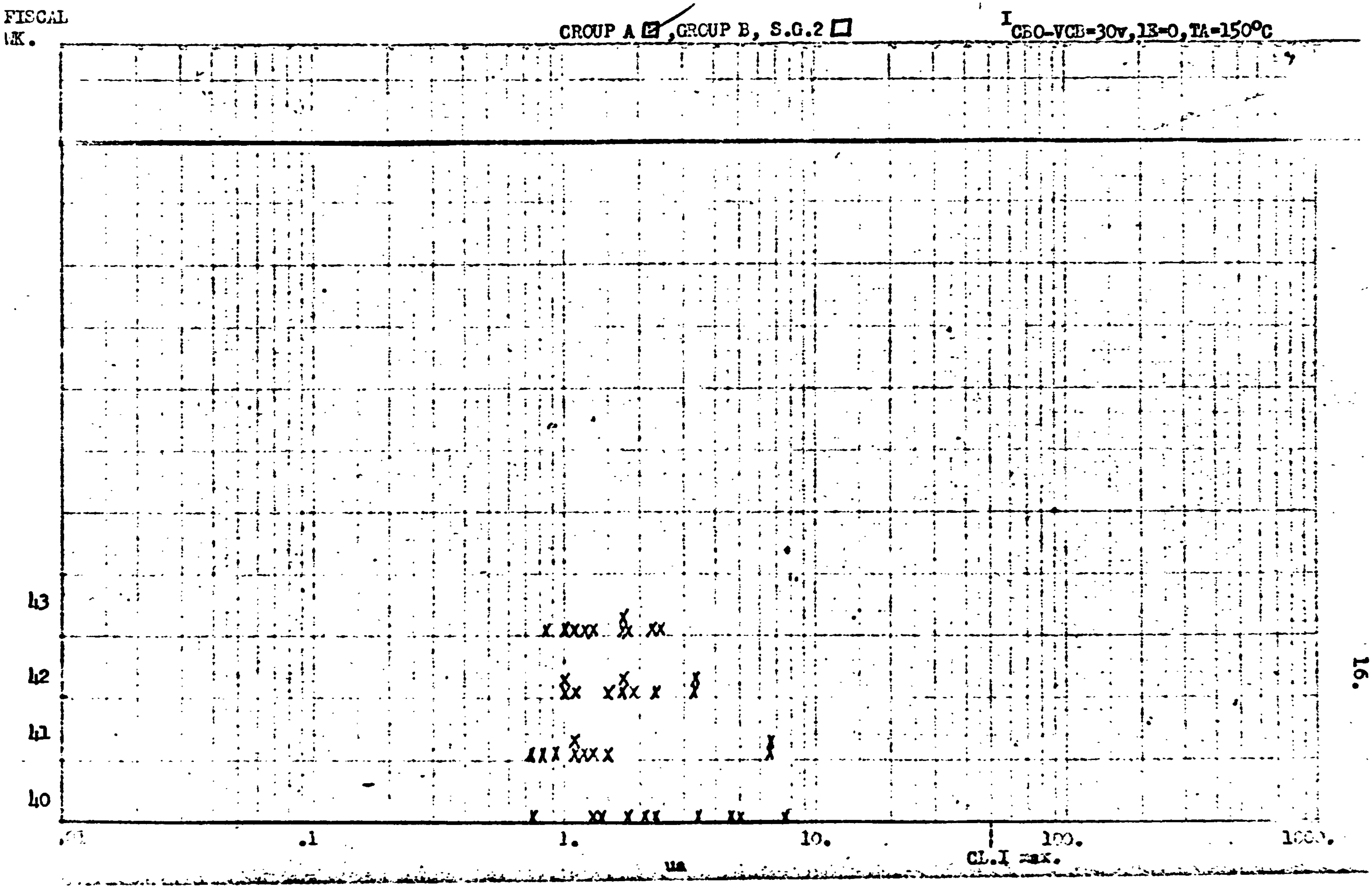
GROUP A ☑, GROUP B, S.G.2 ☐



1962 - 4JD4C LINE, (2N332,2N333,2N335,2N336)

ELECTRICAL MEASUREMENTS PER MILT 19500/37A

GROUP A ☑, GROUP B, S.G.2 ☐



4. CONCLUSIONS

The final design Automatic Passivation System has been released for normal production use so that large scale evaluation of the system may be accomplished. This will be realized by monitoring of the production monitor distributions.

Modifications have begun which will enable the Main Seal welding machine to perform the encapsulation process within the process limits of time, temperature, and gas flow, as orginally outlined for this process.

The majority of the failures on the Temperature Step Stress Test were I_{CBO} failures occuring at temperatures of 345°C or higher.

Initial test yields indicate that the 40°C and 150°C flush temperatures surpass the 300°C flush temperatures in yield.

5. PROGRAM FOR NEXT QUARTER

5.1 PASSIVATION

Devices will be selected and the manufacturing portion of the evaluation run will be completed. These devices will be submitted to the Engineering Reliability Measurement Group and Quality Control for data accumulation.

5.2 HIGH TEMPERATURE MAIN SEALING

Concentration will be placed on the completion of the construction phase of this project in particular completion of modifications and installation in the factory assembly area. Initial runs will be made on this equipment using the high temperature encapsulation process. The specific process parameters will be determined by the results of the encapsulation experiment discussed in another section of this report.

5.3 EXPERIMENTATION AND EVALUATION

The life test data for the encapsulation experiment will be evaluated and smaller side experiments will be started if indications obtained from the life test data evaluation reveal significant results.

5.4 CHARACTERISTIC DISTRIBUTIONS

The monitoring of the electrical parameter distribution of the 4JD4C line will continue. Parameters will be added as necessary or dropped if it is found that they can be controlled via correlation with other parameters.

6. PUBLICATIONS AND REPORTS

6. 1 Formal Quarterly Report

The First Quarterly Report was completed, approved, and distributed.

PROFESSIONAL PERSONNEL

and

TOTAL APPLIED EFFORT

for period covering

31 July 1962 - 31 October 1962

PERSONNEL	MANHOURS
R. L. Lavallee	454
P. W. Olski	
D. P. Smith	
T. E. Gates	
C. L. Jeffers	
R. R. Killian	
P. Marapodi	